THE ELEMENTS OF MARINE ENGINEERING

TABLES AND FORMULAS

THE ELEMENTS

OF

MARINE ENGINEERING

PREPARED FOR STUDENTS OF
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SCRANTON, PA.

Volume IV

TABLES AND FORMULAS

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TABLES AND FORMULAS.

This volume contains all the principal Tables, Rules, and Formulas occurring in the Instruction Papers of the Course. They have been collected and placed in this volume in order to make them convenient for ready reference, so that the student will not be obliged to search the Instruction Papers to find them.

The various Rules and Formulas are here grouped under the titles of the Instruction Papers in which they occur. Following each rule and formula are its number and also that of the article of the Instruction Paper in which it is discussed. Although these numbers do not run consecutively, they may be readily found in the text by noting to what Instruction Paper they belong. Thus: on page 26 of this volume, we see that the formula for "Horsepower of Gears" is followed by "Art. **557.**" Turning back the pages, we find that this formula occurs under the heading "Formulas Used in Mechanics." Therefore, in Art. **557** of the Instruction Paper *Mechanics*, we shall find the discussion of the formula referred to.

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TABLES.

SPECIFIC GRAVITIES AND WEIGHTS PER CUBIC FOOT.

METALS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Osmium	23.00	1,437.5
Platinum	21.50	1,343.8
Gold	19.50	1,218.8
Mercury	13.60	850.0
Lead (cast)	11.35	709.4
Silver	10.50	656.3
Copper (cast)	8.79	549.4
Brass	8.38	523.8
Wrought Iron	7.68	480.0
Cast Iron	7.21	450.0
Steel	7.84	490.0
Tin (cast)	7.29	455.6
Zinc (cast)	6.86	428.8
Antimony	6.71	419.4
Aluminum	2.50	156.3

WOODS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Ash	.845	52.80
Beech	.852	53.25
Cedar	.561	35.06
Cork	.240	15.00
Ebony (American)	1.331	83.19
Lignum-vitæ	1.333	83.30
Maple	.750	46.88
Oak (old)	1.170	73.10
Spruce	.500	31.25
Pine (yellow)	.660	41.20
Pine (white)	.554	34.60
Walnut	.671	41.90

LIQUIDS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Acetic Acid	1.062	66.4
Nitric Acid	1.217	76.1
Sulphuric Acid	1.841	115.1
Muriatic Acid	1.200	75.0
Alcohol	.800	50.0
Turpentine	.870	54.4
Sea Water (ordinary)	1.026	64.1
Milk	1.032	64.5

GASES.

At 32° F., and under a Pressure of One Atmosphere.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Atmospheric Air	1.0000	.08073
Carbonic Acid	1.5290	.12344
Carbonic Oxide	.9674	.07810
Chlorine	2.4400	.19700
Oxygen	1.1056	.08925
Nitrogen	.9736	.07860
Smoke (bituminous coal)	.1020	.00815
Smoke (wood)	.0900	.00727
*Steam at 212° F.	.4700	.03790
Hydrogen	.0692	.00559

* The specific gravity of steam at any temperature and pressure compared with air at the same temperature and pressure is 0.622.

MISCELLANEOUS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Emery	4.00	250
Glass (average)	2.80	175
Chalk	2.78	174
Granite	2.65	166
Marble	2.70	169
Stone (common)	2.52	158
Salt (common)	2.13	133
Soil (common)	1.98	124
Clay	1.93	121
Brick	1.90	118
Plaster Paris (average)	2.00	125
Sand	1.80	113

COEFFICIENTS OF FRICTION.

Description of Surfaces in Contact.	Disposition of Fibers.	State of the Surfaces.	Coefficient of Friction.
Oak on oak	Parallel	Dry	.48
Oak on oak	Parallel	Soaped	.16
Wrought Iron on oak	Parallel	Dry	.62
Wrought Iron on oak	Parallel	Soaped	.21
Cast Iron on oak	Parallel	Dry	.49
Cast Iron on oak	Parallel	Soaped	.19
Wrought Iron on cast iron	—	Slightly Unctuous	.18
Wrought Iron on bronze	—	Slightly Unctuous	.18
Cast Iron on cast iron	—	Slightly Unctuous	.15

TENSILE STRENGTHS OF MATERIALS.

Materials.	Breaking Stress in Pounds per Square Inch.	Working Stress in Pounds per Square Inch.
Timber	10,000	600 to 1,200
Cast Iron	16,000	1,500 to 3,500
Wrought Iron	50,000	5,000 to 12,000
Steel	70,000	6,000 to 13,000

CRUSHING STRENGTHS OF MATERIALS.

Materials.	Crushing Strength in Tons per Square Inch.
Cast Iron	40
Wrought Iron	18
Mild Steel	26
Cast Copper	5
Cast Brass	4.5
Timber (dry)	3.5
Brick	1
Stone	3

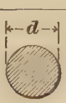
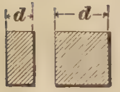
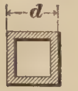
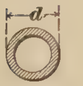
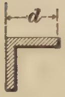
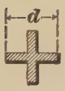
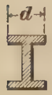
SHEARING STRENGTHS OF MATERIALS.

Materials.	Greatest Shearing Stress in Pounds per Square Inch.	Safe Shearing Stress in Pounds per Square Inch.
Cast Iron	18,000	1,500 to 3,000
Wrought Iron	40,000	4,000 to 10,000
Steel	60,000	5,000 to 12,000

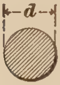
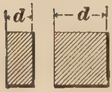
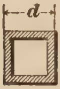
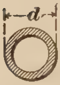
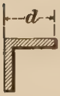
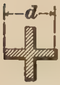
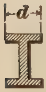
CONSTANTS FOR LINE SHAFTING.

Material of Shaft.	No Pulleys Between Bearings.	Pulleys Between Bearings.
Steel or Cold-Rolled Iron	65	85
Wrought Iron	70	95
Cast Iron	90	120

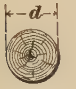
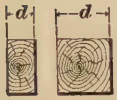
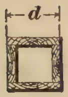
CONSTANTS FOR WROUGHT-IRON PILLARS.

Cross-section of Pillar.		When Both Ends of the Pillar are Flat or Fixed.	When One End of the Pillar is Flat or Fixed, and the Other Round or Movable.	When Both Ends of the Pillar are Round or Movable.
	Round.	2,250	1,500	1,125
	Square or Rectangle.	3,000	2,000	1,500
	Thin Square Tube.	6,000	4,000	3,000
	Thin Round Tube.	4,500	3,000	2,250
	Angle with Equal Sides.	1,500	1,000	750
	Cross with Equal Arms	1,500	1·000	750
	I Beam.	$3{,}000 \times \frac{A}{A+B}$	$2{,}000 \times \frac{A}{A+B}$	$1{,}500 \times \frac{A}{A+B}$

CONSTANTS FOR CAST-IRON PILLARS.

Cross-section of Pillar.	When Both Ends of the Pillar are Flat or Fixed.	When One End of the Pillar is Flat or Fixed, and the Other Round or Movable.	When Both Ends of the Pillar are Round or Movable.
 Round.	281.25	187.5	140.625
 Square or Rectangle.	375.	250.	187.5
 Thin Square Tube.	750.	500.	375.
 Thin Round Tube.	562.5	375.	281.25
 Angle with Equal Sides.	187.5	125.	93.75
 Cross with Equal Arms.	187.5	125.	93.75
 I Beam.	$375 \times \frac{A}{A+B}$	$250 \times \frac{A}{A+B}$	$125 \times \frac{A}{A+B}$

CONSTANTS FOR WOODEN PILLARS.

Cross-section of Pillar.	When Both Ends of the Pillar are Flat or Fixed.	When One End of the Pillar is Flat or Fixed, and the Other Round or Movable.	When Both Ends of the Pillar are Round or Movable.
 Round.	187.5	125.	93.75
 Square or Rectangle.	250.	166.66	125.
 Hollow Square Made of Boards.	500.	333.33	250.

CONSTANTS FOR TRANSVERSE STRENGTH OF BEAMS.

Materials.	Safe Transverse Strength in Pounds.	Materials.	Safe Transverse Strength in Pounds.
Metals:		Woods:	
Cast Iron	100	Birch	35
Wrought Iron	150	Elm	25
Structural Steel	160	Ash	45
Copper	50	Beech	30
Brass	55	Hickory	50
		Maple	60
		Oak (American)	45
		Pine (Pitch)	40
		Pine (White)	30

THE PROPERTIES OF SATURATED STEAM.

Pressure above Vacuum in Pounds per Square Inch.	Temperature, Fahrenheit Degrees.	Quantities of Heat in British Thermal Units.			Weight of a Cubic Foot of Steam in Pounds.	Volume.	
		Required to Raise Temperature of the Water from 32° to t°.	Total Latent Heat at Pressure P.	Total Heat above 32°.		Of a Pound of Steam in Cubic Feet.	Ratio of Vol. of Steam to Vol. of Eq. Weight of Dist. Water at Temp. of Maximum Density.
1	2	3	4	5	6	7	8
p	t	q	L	H	W	V	R
1	102.018	70.040	1043.015	1113.055	.003027	330.4	20623
2	126.302	94.368	1026.094	1120.462	.005818	171.9	10730
3	141.654	109.764	1015.380	1125.144	.008522	117.3	7325
4	153.122	121.271	1007.370	1128.641	.011172	89.51	5588
5	162.370	130.563	1000.899	1131.462	.013781	72.56	4530
6	170.173	138.401	995.441	1133.842	.016357	61.14	3816
7	176.945	145.213	990.695	1135.908	.018908	52.89	3302
8	182.952	151.255	986.485	1137.740	.021436	46.65	2912
9	188.357	156.699	982.690	1139.389	.023944	41.77	2607
10	193.284	161.660	979.232	1140.892	.026437	37.83	2361
11	197.814	166.225	976.050	1142.275	.028911	34.59	2159
12	202.012	170.457	973.098	1143.555	.031376	31.87	1990
13	205.929	174.402	970.346	1144.748	.033828	29.56	1845
14	209.604	178.112	967.757	1145.869	.036265	27.58	1721
14.69	212.000	180.531	966.069	1146.600	.037928	26.37	1646
15	213.067	181.608	965.318	1146.926	.038688	25.85	1614
16	216.347	184.919	963.007	1147.926	.041109	24.33	1519
17	219.452	188.056	960.818	1148.874	.043519	22.98	1434
18	222.424	191.058	958.721	1149.779	.045920	21.78	1359
19	225.255	193.918	956.725	1150.643	.048312	20.70	1292

1	2	3	4	5	6	7	8
p	t	q	L	H	W	V	R
20	227.964	196.655	954.814	1151.469	.050696	19.73	1231.0
22	233.069	201.817	951.209	1153.026	.055446	18.04	1126.0
24	237.803	206.610	947.861	1154.471	.060171	16.62	1038.0
26	242.225	211.089	944.730	1155.819	.064870	15.42	962.3
28	246.376	215.293	941.791	1157.084	.069545	14.38	897.6
30	250.293	219.261	939.019	1158.280	.074201	13.48	841.3
32	254.002	223.021	936.389	1159.410	.078839	12.68	791.8
34	257.523	226.594	933.891	1160.485	.083461	11.98	748.0
36	260.883	230.001	931.508	1161.509	.088067	11.36	708.8
38	264.093	233.261	929.227	1162.488	.092657	10.79	673.7
40	267.168	236.386	927.040	1163.426	.097231	10.28	642.0
42	270.122	239.389	924.940	1164.329	.101794	9.826	613.3
44	272.965	242.275	922.919	1165.194	.106345	9.403	587.0
46	275.704	245.061	920.968	1166.029	.110884	9.018	563.0
48	278.348	247.752	919.084	1166.836	.115411	8.665	540.9
50	280.904	250.355	917.260	1167.615	.119927	8.338	520.5
52	283.381	252.875	915.494	1168.369	.124433	8.037	501.7
54	285.781	255.321	913.781	1169.102	.128928	7.756	484.2
56	288.111	257.695	912.118	1169.813	.133414	7.496	467.9
58	290.374	260.002	910.501	1170.503	.137892	7.252	452.7
60	292.575	262.248	908.928	1171.176	.142362	7.024	438.5
62	294.717	264.433	907.396	1171.829	.146824	6.811	425.2
64	296.805	266.566	905.900	1172.466	.151277	6.610	412.6
66	298.842	268.644	904.443	1173.087	.155721	6.422	400.8
68	300 831	270.674	903.020	1173.694	.160157	6.244	389.8
70	302.774	272.657	901.629	1174.286	.164584	6.076	379.3
72	304.669	274.597	900.269	1174.866	.169003	5.917	369.4
74	306.526	276.493	898.938	1175.431	.173417	5.767	360.0
76	308.344	278.350	897.635	1175.985	.177825	5.624	351.1
78	310.123	280.170	896.359	1176.529	.182229	5.488	342.6
80	311.866	281.952	895.108	1177.060	.186627	5.358	334.5
82	313.576	283.701	893.879	1177.580	.191017	5.235	326.8
84	315.250	285.414	892.677	1178.091	.195401	5.118	319.5
86	316.893	287.096	891.496	1178.592	.199781	5.006	312.5
88	318.510	288.750	890.335	1179.085	.204155	4.898	305.8

1	2	3	4	5	6	7	8
p	t	q	L	H	W	V	R
90	320.094	290.373	889.196	1179.569	.208525	4.796	299.4
92	321.653	291.970	888.075	1180.045	.212892	4.697	293.2
94	323.183	293.539	886.972	1180.511	.217253	4.603	287.3
96	324.688	295.083	885.887	1180.970	.221604	4.513	281.7
98	326.169	296.601	884.821	1181.422	.225950	4.426	276.3
100	327.625	298.093	883.773	1181.866	.230293	4.342	271.1
105	331.169	301.731	881.214	1182.945	.241139	4.147	258.9
110	334.582	305.242	878.744	1183.986	.251947	3.969	247.8
115	337.874	308.621	876.371	1184.992	.262732	3.806	237.6
120	341.058	311.885	874.076	1185.961	.273500	3.656	228.3
125	344.136	315.051	871.848	1186.899	.284243	3.518	219.6
130	347.121	318.121	869.688	1187.809	.294961	3.390	211.6
135	350.015	321.105	867.590	1188.695	.305659	3.272	204.2
140	352.827	324.003	865.552	1189.555	.316338	3.161	197.3
145	355.562	326.823	863.567	1190.390	.326998	3.058	190.9
150	358.223	329.566	861.634	1191.200	.337643	2.962	184.9
160	363.346	334.850	857.912	1192.762	.358886	2.786	173.9
170	368.226	339.892	854.359	1194.251	.380071	2.631	164.3
180	372.886	344.708	850.963	1195.671	.401201	2.493	155.6
190	377.352	349.329	847.703	1197.032	.422280	2.368	147.8
200	381.636	353.766	844.573	1198.339	.443310	2.256	140.8
210	385.759	358.041	841.556	1199.597	.464295	2.154	134.5
220	389.736	362.168	838.642	1200.810	.485237	2.061	128.7
230	393.575	366.152	835.828	1201.980	.506139	1.976	123.3
240	397.285	370.008	833.103	1203.111	.527003	1.898	118.5
250	400.883	373.750	830.459	1204.209	.547831	1.825	114.0
260	404.370	377.377	827.896	1205.273	.568626	1.759	109.8
270	407.755	380.905	825.401	1206.306	.589390	1.697	105.9
280	411.048	384.337	822.973	1207.310	.610124	1.639	102.3
290	414.250	387.677	820.609	1208.286	.630829	1.585	99.0
300	417.371	390.933	818.305	1209.238	.651506	1.535	95.8

SPECIFIC HEAT OF VARIOUS SUBSTANCES.

Substance.	Specific Heat.	Substance.	Specific Heat.
Water	1.0000	Ice	.5040
Sulphur	.2026	Steam (superheated)	.4805
Iron	.1138	Air	.2375
Copper	.0951	Oxygen	.2175
Silver	.0570	Hydrogen	3.4090
Tin	.0562	Nitrogen	.2438
Mercury	.0333	Carbon Monoxide	.2479
Lead	.0314	Carbon Dioxide	.2170

RELATIVE POSITIONS OF CRANK AND ECCENTRIC.

	Kind of Valve.	Kind of Rocker-Arm.	Angle Between Crank and Eccentric.	Position of Eccentric Relative to Crank.
I	Direct	Direct	90° + angle of advance	Ahead of crank
II	Direct	Reversing	90° − angle of advance	Behind crank
III	Indirect	Direct	90° − angle of advance	Behind crank
IV	Indirect	Reversing	90° + angle of advance	Ahead of crank

The above table may be applied equally well whichever direction the engine runs. It is simply necessary to remember that to set the eccentric *ahead* of the crank is to set it so that it reaches a given point in its revolution before the crank reaches the same point in its revolution.

STRENGTH OF RIVETED

Thickness of Material Required.	Greatest Length of Sections Allowable, 5 Feet.				Greatest Length of Sections Allowable, 3 Feet.												
	Least Thickness of Material Allowable.				Least Thickness of Material Allowable.												
	.18	.20	.21	.21	.22	.22	.23	.24	.25	.26	.27	.28	.29	.30	.31	.32	.33
	Diameter of Flues.																
	Over 6 and not over 7 in.	Over 7 and not over 8 in.	Over 8 and not over 9 in.	Over 9 and not over 10 in.	Over 10 and not over 11 in.	Over 11 and not over 12 in.	Over 12 and not over 13 in.	Over 13 and not over 14 in.	Over 14 and not over 15 in.	Over 15 and not over 16 in.	Over 16 and not over 17 in.	Over 17 and not over 18 in.	Over 18 and not over 19 in.	Over 19 and not over 20 in.	Over 20 and not over 21 in.	Over 21 and not over 22 in.	Over 22 and not over 23 in.
	Pounds Pressure Allowable.																
.18	189	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
.19	194	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
.20	199	184	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
.21	204	189	179	174	...	...	...	...	...	...	...	...	...	...	...	...	...
.22	...	194	184	179	172	158	...	...	...	...	...	...	...	...	...	...	...
.23	...	199	189	184	179	165	152	...	...	...	...	...	...	...	...	...	...
.24	...	204	194	189	187	172	158	147	...	...	...	...	...	...	...	...	...
.25	...	...	199	194	195	179	165	153	143	...	...	...	...	...	...	...	...
.26	...	...	204	199	203	186	172	159	148	139	...	...	...	...	...	...	...
.27	...	...	...	204	211	193	178	165	154	145	136	...	...	...	...	...	...
.28	...	...	...	...	...	200	185	172	160	150	141	134	...	...	...	...	...
.29	...	...	...	...	...	207	191	178	166	155	146	138	131	...	...	...	...
.30	...	...	...	...	...	...	198	184	172	161	152	143	135	129	...	...	...
.31	...	...	...	...	...	...	205	190	178	166	156	148	140	133	126	...	...
.32	...	...	...	...	...	...	...	196	183	171	161	153	145	137	131	125	...
.33	...	...	...	...	...	...	...	202	189	177	167	157	149	141	135	129	122
.34	...	...	...	...	...	...	...	...	194	182	172	162	154	146	139	132	126
.35	...	...	...	...	...	...	...	...	200	187	177	167	159	150	143	137	130
.36	...	...	...	...	...	...	...	...	...	193	182	172	163	154	147	141	134
.37	...	...	...	...	...	...	...	...	...	...	187	177	168	159	151	145	138
.38	...	...	...	...	...	...	...	...	...	...	...	182	172	163	155	149	142
.39	...	...	...	...	...	...	...	...	...	...	...	...	176	167	159	152	146
.40	...	...	...	...	...	...	...	...	...	...	...	...	...	172	163	156	150
.41	...	...	...	...	...	...	...	...	...	...	...	...	...	...	167	160	153
.42	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	164	157
.43	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	160

OR LAP-WELDED FLUES.

Thickness of Material Required.	Greatest Length of Sections Allowable, 30 Inches.																
	Least Thickness of Material Allowable.																
	.34	.35	.36	.37	.38	.39	.40	.41	.42	.43	.44	.45	.46	.47	.48	.49	.50
	Diameter of Flues.																
	Over 23 and not over 24 in.	Over 24 and not over 25 in.	Over 25 and not over 26 in.	Over 26 and not over 27 in.	Over 27 and not over 28 in.	Over 28 and not over 29 in.	Over 29 and not over 30 in.	Over 30 and not over 31 in.	Over 31 and not over 32 in.	Over 32 and not over 33 in.	Over 33 and not over 34 in.	Over 34 and not over 35 in.	Over 35 and not over 36 in.	Over 36 and not over 37 in.	Over 37 and not over 38 in.	Over 38 and not over 39 in.	Over 39 and not over 40 in.
	Pounds Pressure Allowable.																
.34	121	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
.35	125	120	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
.36	129	123	119	...	...	...	...	...	...	...	...	...	...	...	...	...	...
.37	132	127	122	117	...	...	...	...	...	...	...	...	...	...	...	...	...
.38	136	130	125	121	116	...	...	...	...	...	...	...	...	...	...	...	...
.39	139	133	129	124	119	115	...	...	...	...	...	...	...	...	...	...	...
.40	143	137	132	127	123	118	115	...	...	...	...	...	...	...	...	...	...
.41	147	141	135	130	126	121	118	114	...	...	...	...	...	...	...	...	...
.42	151	144	139	133	129	124	120	117	112	...	...	...	...	...	...	...	...
.43	154	147	142	137	132	127	123	119	115	112	...	...	...	...	...	...	...
.44	157	151	145	140	135	130	126	122	118	115	110	...	...	...	...	...	...
.45	...	155	148	143	138	133	129	124	121	117	113	110	...	...	...	...	...
.46	...	...	151	146	141	136	132	127	124	120	116	112	109	...	...	...	...
.47	...	...	...	149	144	139	135	130	126	122	118	115	112	109	...	...	...
.48	...	...	...	...	147	142	138	133	129	125	120	117	114	111	108	...	...
.49	...	...	...	...	...	145	140	135	131	127	123	120	116	113	111	108	...
.50	...	...	...	...	...	...	143	138	134	130	126	122	119	116	113	110	107
.51	...	...	...	...	...	...	...	141	137	133	129	125	121	118	115	112	109
.52	...	...	...	...	...	...	...	...	140	135	131	127	123	120	117	114	111
.53	...	...	...	...	...	...	...	...	...	138	134	129	126	123	119	116	113
.54	...	...	...	...	...	...	...	...	...	...	137	132	128	125	122	118	116
.55	...	...	...	...	...	...	...	...	...	...	...	135	131	127	124	121	118
.56	...	...	...	...	...	...	...	...	...	...	...	...	133	130	126	123	120
.57	...	...	...	...	...	...	...	...	...	...	...	...	...	132	128	125	122
.58	...	...	...	...	...	...	...	...	...	...	...	...	...	...	131	127	124
.59	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	130	126
.60	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	129

SPACING OF LINE-SHAFT BEARINGS.

Diameter of Shaft in Inches.	Distance Between Bearings in Feet.	
	Wrought-Iron Shaft.	Steel Shaft.
2	11	11.5
3	13	13.75
4	15	15.75
5	17	18.25
6	19	20.
7	21	22.25
8	23	24.
9	25	26.

CONSTANTS FOR APPARENT CUT-OFFS USED IN DETERMINING M. E. P.

Cut-off.	Constant.	Cut-off.	Constant.	Cut-off.	Constant.
$\frac{1}{6}$	.566	$\frac{3}{8}$	.771	$\frac{2}{3}$	.917
$\frac{1}{5}$	.603	.4	.789	.7	.926
$\frac{1}{4}$	.659	$\frac{1}{2}$	.847	$\frac{3}{4}$	.937
.3	.708	.6	.895	.8	.944
$\frac{1}{3}$	.743	$\frac{5}{8}$	.904	$\frac{7}{8}$	.951

EVAPORATIVE POWER OF COAL.

The evaporation per pound of coal for Scotch and fire-box boilers may be taken as follows:

Coal per hour per sq. ft. of grate area. From	6–10	10–14	14–18	18–20
Pounds of water evaporated per pound of coal	10	9	8.25	7.5

For water-tube boilers add $\frac{1}{2}$ pound to the evaporation.

THE THICKNESS OF BOILER TUBES.

The thickness of boiler tubes, as required by the Board of Supervising Inspectors, is given in the table below:

Outside Diameter.	Thickness.	Outside Diameter.	Thickness.
1	.072	4½	.134
1¼	.072	5	.148
1½	.083	6	.165
1¾	.095	7	.165
2	.095	8	.165
2¼	.095	9	.180
2½	.109	10	.203
2¾	.109	11	.220
3	.109	12	.229
3¼	.120	13	.238
3½	.120	14	.248
3¾	.120	15	.259
4	.134	16	.270

SATURATION AND BOILING POINTS.

Saturation.	Boiling Point.	Saturation.	Boiling Point.
$\frac{0}{32}$	212.0° F.	$\frac{7}{32}$	220.3° F.
$\frac{1}{32}$	213.2° F.	$\frac{8}{32}$	221.5° F.
$\frac{2}{32}$	214.4° F.	$\frac{9}{32}$	222.7° F.
$\frac{3}{32}$	215.5° F.	$\frac{10}{32}$	223.8° F.
$\frac{4}{32}$	216.7° F.	$\frac{11}{32}$	225.0° F.
$\frac{5}{32}$	217.9° F.	$\frac{12}{32}$	226.1° F.
$\frac{6}{32}$	219.1° F.		

At $\frac{12}{32}$ saturation the water becomes saturated; that is, it will not dissolve any more matter.

In the above table, the exact boiling points of sea-water at different degrees of saturation are given. As water will boil at a temperature varying with the pressure of the atmosphere, the boiling points given in the table are correct for but one pressure, namely, 30 in. of mercury.

CONSTANTS USED IN CALCULATING SPEED OF VESSELS.

Description of Vessel.	Speed, Knots.	k.
Under 200 feet, fair........	9–10	200
Under 200 feet, fine........	9–10	230
Under 200 feet, fine.......	10–11	210
Under 200 feet, fine........	11–12	200
From 200–250 feet, fair.....	9–11	220
From 200–250 feet, fine	9–11	240
From 200–250 feet, fine	11–12	220
From 250–300 feet, fair.....	9–11	250
From 250–300 feet, fair.....	11–13	220
From 250–300 feet, fine	9–11	260
From 250–300 feet, fine	11–13	240
From 250–300 feet, fine	13–15	200
From 300–400 feet, fair.....	9–11	260
From 300–400 feet, fair.....	11–13	240
From 300–400 feet, fine	11–13	260
From 300–400 feet, fine	13–15	240
From 300–400 feet, fine	15–17	190
Above 400 feet, fine........	15–17	240

To determine whether a vessel is fair or fine, it is usual to compare its displacement in cubic feet with the volume of a rectangular box having a length equal to the length of the vessel on the water-line, a width equal to the beam, and a depth equal to the draught of the vessel diminished by the depth of the keel. If the displacement is .55 of the volume of the box, or less, the vessel is fine; if above .55 and less than .70, fair. The quotient obtained by dividing the displacement by the contents of the imaginary box is called the **coefficient of fineness.**

SATURATION AND MANAGEMENT OF FEED.

The following scheme shows the method of regulating the saturation in a boiler containing 100,000 pounds of sea-water. The saturation is not to exceed $\frac{2}{32}$:

	Number of Pounds of Water in Boiler.	Pounds of Solid Matter.
Evaporated into steam.......	100,000	3,125
Fed in to make up at $\frac{1}{32}$.....	100,000	3,125
Water in boiler..............	100,000	6,250
Blown off....................	20,000	1,250
Water in boiler..............	80,000	5,000
Fed in at $\frac{1}{32}$...............	20,000	625
Water in boiler..............	100,000	5,625
Evaporated...................	20,000	Steam
Water in boiler..............	80,000	5,625
Fed in at $\frac{1}{32}$...............	20,000	625
Water in boiler..............	100,000	6,250

FORMULAS.

FORMULAS USED IN MENSURATION.

THE PARALLELOGRAM.

h = altitude of parallelogram, expressed in any unit;
b = base of parallelogram, expressed in same unit;
A = area of parallelogram.

$$A = hb. \qquad \textbf{(44.)} \quad \text{Art. } \textbf{375.}$$

$$\left.\begin{aligned} h &= \frac{A}{b}. \\ b &= \frac{A}{h}. \end{aligned}\right\} \qquad \textbf{(46.)} \quad \text{Art. } \textbf{377.}$$

THE TRAPEZOID.

h = altitude of a trapezoid;
l = length of one of its parallel sides;
l_1 = length of the other parallel side;
A = area of trapezoid.

$$A = h\left(\frac{l + l_1}{2}\right). \qquad \textbf{(45.)} \quad \text{Art. } \textbf{376.}$$

THE TRIANGLE.

A, B, C = the number of degrees in the three angles, respectively.

$$\left.\begin{aligned} A &= 180° - B - C. \\ B &= 180° - A - C. \\ C &= 180° - B - A. \end{aligned}\right\} \qquad \textbf{(47.)} \quad \text{Art. } \textbf{382.}$$

A_1 and B_1 = the number of degrees in the two acute angles, respectively, of any right-angled triangle.

$$\left.\begin{aligned} A_1 &= 90° - B_1. \\ B_1 &= 90° - A_1. \end{aligned}\right\} \qquad \textbf{(48.)} \quad \text{Art. } \textbf{383.}$$

a and b = the lengths, respectively, of the two short sides of a right-angled triangle;
c = length of third side, or hypotenuse.

$$c = \sqrt{a^2 + b^2}. \qquad \text{(49.) Art. } \mathbf{385.}$$

$$\left.\begin{aligned} a &= \sqrt{c^2 - b^2}. \\ b &= \sqrt{c^2 - a^2}. \end{aligned}\right\} \qquad \text{(50.) Art. } \mathbf{385.}$$

h = altitude of given triangle;
b = base of triangle;
A = area of triangle.

$$A = \frac{b\,h}{2}. \qquad \text{(51.) Art. } \mathbf{386.}$$

$$\left.\begin{aligned} h &= \frac{2\,A}{b}. \\ b &= \frac{2\,A}{h}. \end{aligned}\right\} \qquad \text{(52.) Art. } \mathbf{386.}$$

THE POLYGON.

N = number of sides in any regular polygon.
D = number of degrees in each interior angle.

$$D = \frac{180\,(N - 2)}{N}. \qquad \text{(53.) Art. } \mathbf{389.}$$

l = length of side of any regular polygon;
d = perpendicular distance from center of polygon (i.e. center of circumscribing circle) to any side;
N = number of sides;
A = area of polygon.

$$A = \frac{d\,l\,N}{2}. \qquad \text{(54.) Art. } \mathbf{390.}$$

THE CIRCLE.

d = diameter of circle;
c = circumference;
A = area;
l = length of arc;
n = number of degrees in arc;
a = area of sector;

a_1 = area of segment;
n_1 = number of degrees in sector;
$\pi = 3.1416$.

$c = \pi d.$ **(55.)** Art. **402.**

$d = \frac{c}{\pi}.$ **(56.)** Art. **403.**

$l = \frac{c\,n}{360}.$ **(57.)** Art. **404.**

$A = \frac{\pi d^2}{4} = .7854\,d^2.$ **(58.)** Art. **405.**

$d = \sqrt{\frac{A}{.7854}}.$ **(59.)** Art. **406.**

$a = \frac{n_1 A}{360}.$ **(60.)** Art. **407.**

$a_1 = \frac{4\,h^2}{3}\sqrt{\frac{d}{h} - .608}.$ **(61.)** Art. **408.**

THE PRISM, CYLINDER, CONE, AND PYRAMID.

p = perimeter of the base of the prism, cylinder, cone, or pyramid;
h = altitude;
h_1 = slant height of cone;
A = area of convex surface;
a = area of base;
A_1 = total area of outside surface;
V = volume.

$$\text{Prism and cylinder}\begin{cases} \left.\begin{aligned} A &= p\,h. \\ A_1 &= A + 2a. \end{aligned}\right\} & \textbf{(62.) Art. 416.} \\ V = a\,h. & \textbf{(63.) Art. 417.} \end{cases}$$

$$\text{Pyramid and cone}\begin{cases} \left.\begin{aligned} A &= \frac{p\,h_1}{2}. \\ A_1 &= A + a. \end{aligned}\right\} & \textbf{(64.) Art. 422.} \\ V = \frac{a\,h}{3}. & \textbf{(65.) Art. 423.} \end{cases}$$

FRUSTUM OF CONE OR PYRAMID.

p = perimeter of upper base of frustum;
p_1 = perimeter of lower base of frustum;
h = altitude of frustum;
h_1 = slant height;
a = area of upper base;
a_1 = area of lower base;
A = convex surface;
A_1 = total surface;
V = volume.

$$\left.\begin{aligned} A &= \left(\frac{p+p_1}{2}\right)h_1. \\ A_1 &= A + a + a_1. \end{aligned}\right\} \quad \textbf{(66.)} \quad \text{Art. } \mathbf{426.}$$

$$V = (a + a_1 + \sqrt{a\,a_1})\frac{h}{3} \quad \textbf{(67.)} \quad \text{Art. } \mathbf{427.}$$

THE SPHERE.

d = diameter of sphere;
A = area of surface;
V = volume;
π = 3.1416.

$$A = \pi d^2. \quad \textbf{(68.)} \quad \text{Art. } \mathbf{429.}$$

$$V = \frac{1}{6}\pi d^3 = .5236\, d^3. \quad \textbf{(69.)} \quad \text{Art. } \mathbf{430.}$$

THE CYLINDRICAL RING.

a = area of cross-section of ring;
c = circumference of cross-section;
D = mean circumference of ring;
A = convex area of ring;
V = volume of ring.

$$A = Dc. \quad \textbf{(70.)} \quad \text{Art. } \mathbf{431.}$$

$$V = Da. \quad \textbf{(71.)} \quad \text{Art. } \mathbf{432.}$$

FORMULAS USED IN MECHANICS.

MOTION AND VELOCITY.

s = distance traveled by moving body;
v = uniform velocity of body;
t = the time.

$$v = \frac{s}{t}. \qquad \text{(72.) Art. } \mathbf{465.}$$

$$s = v\,t. \qquad \text{(73.) Art. } \mathbf{467.}$$

$$t = \frac{s}{v}. \qquad \text{(74.) Art. } \mathbf{468.}$$

CENTER OF GRAVITY.

w = weight of smaller body;
W = weight of larger body;
l = distance between centers of gravity of the two bodies;
l_1 = distance from the center of gravity of the two to center of gravity of larger body.

$$l_1 = \frac{w\,l}{W + w}. \qquad \text{(75.) Art. } \mathbf{478.}$$

THE LEVER.

P = the power;
W = the weight;
a = perpendicular distance of power from fulcrum = power arm;
b = perpendicular distance of weight from fulcrum = weight arm;
$a_1, a_2, a_3, \ldots\ldots$ = power arms of compound lever;
$b_1, b_2, b_3, \ldots\ldots$ = weight arms of compound lever.

$$P a = W b. \qquad \text{(79.) Art. } \mathbf{486.}$$

$$P \times a_1 \times a_2 \times a_3 \times \ldots\ldots = W \times b_1 \times b_2 \times b_3 \times \ldots\ldots \qquad \text{(80.) Art. } \mathbf{490.}$$

SPEED AND POWER OF PULLEYS.

D = diameter of driving pulley;
d = diameter of driven pulley;
N = revolutions per minute of driving pulley;
n = revolutions per minute of driven pulley.

$$D = \frac{dn}{N}. \qquad \textbf{(81.)} \quad \text{Art. } \mathbf{496.}$$

$$d = \frac{DN}{n}. \qquad \textbf{(82.)} \quad \text{Art. } \mathbf{497.}$$

$$n = \frac{DN}{d}. \qquad \textbf{(83.)} \quad \text{Art. } \mathbf{498.}$$

$$N = \frac{dn}{D}. \qquad \textbf{(84.)} \quad \text{Art. } \mathbf{499.}$$

$D_1, D_2, D_3, \ldots$ = diameters of driving pulleys;
$d_1, d_2, d_3, \ldots$ = diameters of driven pulleys.
P = power exerted;
W = weight lifted

$$\left.\begin{aligned} P &= \frac{W \times d_1 \times d_2 \times d_3 \times \ldots}{D_1 \times D_2 \times D_3 \times \ldots}. \\ W &= \frac{P \times D_1 \times D_2 \times D_3 \times \ldots}{d_1 \times d_2 \times d_3 \times \ldots}. \end{aligned}\right\} \textbf{(85.)} \quad \text{Art. } \mathbf{501.}$$

GEAR-WHEELS.

D = pitch diameter of wheel;
P = pitch;
T = number of teeth.

$$D = \frac{PT}{3.1416}. \qquad \textbf{(86.)} \quad \text{Art. } \mathbf{508.}$$

$$T = \frac{3.1416\,D}{P}. \qquad \textbf{(87.)} \quad \text{Art. } \mathbf{508.}$$

$$P = \frac{3.1416\,D}{T}. \qquad \textbf{(88.)} \quad \text{Art. } \mathbf{508.}$$

N = revolutions per minute of driving wheel;
n = revolutions per minute of driven wheel;
T = number of teeth in the driving wheel;
t = number of teeth in the driven wheel.

$$T = \frac{t\,n}{N}. \qquad \textbf{(89.)} \quad \text{Art. } \mathbf{511.}$$

$$t = \frac{T\,N}{n}. \qquad \textbf{(90.)} \quad \text{Art. } \mathbf{511.}$$

$$n = \frac{T\,N}{t}. \qquad \textbf{(91.)} \quad \text{Art. } \mathbf{511.}$$

$$N = \frac{t\,n}{T}. \qquad \textbf{(92.)} \quad \text{Art. } \mathbf{511.}$$

PULLEYS.

n = number of parts of rope supporting load; one continuous rope being used, and free end not counted;
P = power;
W = weight lifted.

$$\left.\begin{array}{l} W = P\,n. \\ P = \dfrac{W}{n}. \end{array}\right\} \qquad \textbf{(93.)} \quad \text{Art. } \mathbf{516.}$$

THE INCLINED PLANE.

l = length of inclined plane;
b = base of plane;
h = height of plane;
P = power;
W = weight.

When the power acts parallel to the plane:

$$P = \frac{W\,h}{l}; \quad W = \frac{P\,l}{h}. \qquad \textbf{(94.)} \quad \text{Art. } \mathbf{518.}$$

When the power acts parallel to the base:

$$P = \frac{W\,h}{b}; \quad W = \frac{P\,b}{h}. \qquad \textbf{(95.)} \quad \text{Art. } \mathbf{518.}$$

THE SCREW.

p = pitch of screw;
r = perpendicular distance from center of screw to line of direction of power;
P = power;
W = weight.

$$\left.\begin{aligned} P&=\frac{Wp}{6.2832\,r}=\frac{Wp}{2\pi r}.\\ W&=\frac{6.2832\,Pr}{p}=\frac{2\pi rP}{p}.\end{aligned}\right\}\qquad \text{(96.)}\quad \text{Art. } \mathbf{521.}$$

FRICTION ON GUIDES.

P = total pressure on piston;

l = length of main rod;

r = length of crank;

c = coefficient of friction between cross-head and guides;

F = effort required to overcome friction.

$$F=\frac{Prc}{l}.\qquad \text{(97.)}\quad \text{Art. } \mathbf{532.}$$

CENTRIFUGAL FORCE.

F = centrifugal force in pounds;

W = weight of revolving body in pounds;

R = radius of circle described by body in feet;

N = revolutions per minute.

$$F=.00034\,WRN^2.\qquad \text{(98.)}\quad \text{Art. } \mathbf{535.}$$

WORK AND ENERGY.

F = force required to overcome the resistance;

S = space through which the resistance acts;

U = work done in foot-pounds;

T = time occupied in minutes;

H = horsepower;

W = weight of a body;

h = vertical distance the body is raised.

$$U=FS=Wh.\qquad \text{(99.)}\quad \text{Art. } \mathbf{541.}$$

$$H=\frac{FS}{33{,}000\,T}=\frac{Wh}{33{,}000\,T}.\qquad \text{Art. } \mathbf{543.}$$

W = weight of moving body in pounds;

v = velocity of body in feet per second;

E_k = kinetic energy of body in foot-pounds.

$$E_k=\frac{Wv^2}{64.32}.\qquad \text{(100.)}\quad \text{Art. } \mathbf{545.}$$

BELTS.

D = diameter of one pulley;
D_1 = diameter of other pulley;
L = distance between shafts;
B = length of *open* belt.

$$B = 3\tfrac{1}{4}\left(\frac{D + D_1}{2}\right) + 2L. \qquad \textbf{(101.)} \quad \text{Art. } \textbf{551.}$$

W = width of single belt in inches;
W_1 = width of double belt in inches;
H = horsepower transmitted by belt;
S = speed of belt in feet per minute.

$$W = \frac{800\,H}{S}. \qquad \textbf{(102.)} \quad \text{Art. } \textbf{552.}$$

$$H = \frac{WS}{800}. \qquad \textbf{(103.)} \quad \text{Art. } \textbf{553.}$$

$$W_1 = \frac{2}{3}W. \qquad \textbf{(104.)} \quad \text{Art. } \textbf{555.}$$

HORSEPOWER OF GEARS.

p = pitch of teeth of gear (breadth of face is $2\frac{1}{2}$ to $3p$);
s = speed of point on pitch circle in feet per minute;
H = horsepower transmitted by gear.

$$H = .01\,sp^2. \qquad \textbf{(105.)} \quad \text{Art. } \textbf{557.}$$

LIQUID PRESSURE.

a = area of a submerged surface in square inches;
d = distance in inches of center of gravity of surface from surface of liquid;
w = weight of a cubic inch of the fluid in pounds;
p = pressure on surface of liquid, pounds per sq. in.;
P = total pressure on submerged surface in pounds.

$$P = a(dw + p). \quad \textbf{(106.)}\ \textbf{(107.)}\ \textbf{(108.)} \quad \text{Arts. } \textbf{565-572.}$$

VOLUME AND PRESSURE OF GASES.

p = original pressure;
v = original volume;
p_1 = final pressure;
v_1 = final volume.

$$p_1 = \frac{p\,v}{v_1}. \qquad \textbf{(109.)} \quad \text{Art. } \textbf{594.}$$

$$v_1 = \frac{p\,v}{p_1}. \qquad \textbf{(110.)} \quad \text{Art. } \textbf{595.}$$

STRENGTH OF BARS IN TENSION.

W = safe load in pounds;
A = area of minimum cross-section in square inches;
S = working stress in pounds per square inch (see table of Tensile Strengths of Materials).

$$W = A\,S. \qquad \textbf{(111.)} \quad \text{Art. } \textbf{626.}$$

$$A = \frac{W}{S}. \qquad \textbf{(112.)} \quad \text{Art. } \textbf{626.}$$

$$S = \frac{W}{A}. \qquad \textbf{(113.)} \quad \text{Art. } \textbf{626.}$$

STRENGTH OF CHAINS.

W = safe load in pounds for stud-link chains;
W_1 = safe load in pounds for close-link chains;
D = diameter of iron from which link is made, inches.

$$W = 18{,}000\,D^2. \qquad \textbf{(114.)} \quad \text{Art. } \textbf{628.}$$

$$W_1 = 12{,}000\,D^2. \qquad \textbf{(115.)} \quad \text{Art. } \textbf{628.}$$

STRENGTH OF ROPES.

C = circumference of **hemp** rope in inches;
W = maximum working load in pounds.

$$W = 100\,C^2. \qquad \textbf{(116.)} \quad \text{Art. } \textbf{630.}$$

$$C = .1\sqrt{W}. \qquad \textbf{(117.)} \quad \text{Art. } \textbf{630.}$$

C = circumference of **wire** rope in inches;
W = maximum working load in pounds;
k = constant: 600 for iron; 1,000 for steel;
c = constant: .0408 for iron; .0316 for steel.

$$W = k C^2. \qquad \textbf{(118.)} \text{ Art. } \textbf{633.}$$

$$C = c \sqrt{W}. \qquad \textbf{(119.)} \text{ Art. } \textbf{633.}$$

STRENGTH OF PILLARS.

C = crushing strength in tons per sq. in. (see table of Crushing Strengths of Materials);
S = sectional area in inches;
L = length in inches;
d = least thickness of rectangular pillar, or diameter of round pillar, in inches;
W = breaking load in tons;
a = constant (see table of Constants for Pillars).

$$W = \frac{C S}{1 + \frac{L^2}{a d^2}}. \qquad \textbf{(121.)} \text{ Art. } \textbf{638.}$$

STRENGTH OF BEAMS.

d = depth of beam in inches;
w = width of beam in inches;
d_1 = diameter of cylindrical beam in inches;
L = length between supports in feet
= distance between load and fixed end, in the case of cantilevers.
S = safe transverse strength (see table of Constants for Transverse Strength of Beams).
W = safe load in pounds.

Cantilevers. (Load at End.)

$$W = \frac{d^2 w S}{L}. \qquad \textbf{(122.)} \text{ Art. } \textbf{642.}$$

$$W = \frac{.6 d_1^3 S}{L}. \qquad \textbf{(123.)} \text{ Art. } \textbf{643.}$$

If the load is distributed uniformly, multiply the results obtained from formulas **122** and **123** by 2.

Beams Supported at the Ends.

$$W = \frac{4\,d^2\,w\,S}{L}.$$ (**124.**) Art. **644.**

$$W = \frac{4\,d_1^3 \times .6\,S}{L}.$$ (**125.**) Art. **645.**

If the load is uniformly distributed, multiply the results obtained by 2.

SHEARING STRENGTH OF MATERIALS.

a = area of cross-section in square inches;
S = safe shearing stress (see table of Shearing Strengths of Materials);
W = safe load in pounds.

$$W = a\,S.$$ (**126.**) Art. **649.**

LINE SHAFTING.

D = diameter of shaft;
R = revolutions per minute;
H = horsepower transmitted;
C = constant (see table of Constants for Line Shafting)

$$H = \frac{D^3\,R}{C}.$$ (**127.**) Art. **653.**

$$R = \frac{C\,H}{D^3}.$$ (**128.**) Art. **654.**

$$D = \sqrt[3]{\frac{C\,H}{R}}.$$ (**129.**) Art. **655.**

FORMULAS USED IN STEAM AND STEAM BOILERS.

SPECIFIC HEAT.

W = weight of body in pounds;
t = temperature before heat is applied;
t_1 = temperature after heat is applied;
c = specific heat of body;
U = number of B. T. U. required to raise temperature of body from t to t_1.

$$U = c\,W(t_1 - t). \qquad \textbf{(130.)} \quad \text{Art. } \textbf{667.}$$

TEMPERATURE OF MIXTURES.

$w, w_1, w_2, \ldots$ = weights of the several substances, respectively;
$c, c_1, c_2, \ldots$ = specific heats of the substances, respectively;
$t, t_1, t_2, \ldots$ = temperatures of the substances, respectively;
T = final temperature of mixture.

$$T = \frac{w\,c\,t + w_1 c_1 t_1 + w_2 c_2 t_2 + \ldots}{w\,c + w_1 c_1 + w_2 c_2 + \ldots}. \qquad \textbf{(131.)} \quad \text{Art. } \textbf{670.}$$

Mixture of Steam and Water.

W = weight of steam in pounds;
w = weight of water in pounds;
t_1 = temperature of steam;
t = temperature of water;
T = final temperature of mixture;
L = latent heat of steam at the given temperature.

$$T = \frac{W(L + t_1) + w\,t}{W + w}. \qquad \textbf{(132.)} \quad \text{Art. } \textbf{671.}$$

PROPORTIONS OF RIVETED JOINTS.

p = pitch of rivets in inches;
p_m = maximum pitch allowable;
n = number of rows of rivets;
p_d = diagonal pitch in inches;
d = diameter of rivets in inches;
T = thickness of plate in inches;
V = distance between rows of rivets in inches;
E = distance from center of rivet to edge of plate in inches.

When plate and rivets are iron, for single-riveted lap joints:

$$d = T + \tfrac{3}{8}''. \qquad \textbf{(132}a.\textbf{)} \quad \text{Art. } \textbf{716}b.$$

For double-riveted lap joints:

$$d = T + \tfrac{5}{16}''. \qquad \textbf{(132}b.\textbf{)} \quad \text{Art. } \textbf{716}b.$$

When plate and rivets are steel, for single-riveted lap joints:

$$d = T + \tfrac{7}{16}''. \qquad \textbf{(132}c.\textbf{)} \quad \text{Art. } \textbf{716}b.$$

For double-riveted lap joints:

$$d = T + \tfrac{3}{8}''. \qquad \textbf{(132}d.\textbf{)} \quad \text{Art. } \textbf{716}b.$$

For iron plates and iron rivets:

$$p = \frac{.7854\, d^2 n}{T} + d. \qquad \textbf{(132}e.\textbf{)} \quad \text{Art. } \textbf{716}b.$$

For steel plates and steel rivets:

$$p = \frac{23 \times .7854\, d^2 n}{28\, T} + d. \qquad \textbf{(132}f.\textbf{)} \quad \text{Art. } \textbf{716}b.$$

For all kinds of joints and material:

$$E = 1.5\, d. \qquad \textbf{(132}g.\textbf{)} \quad \text{Art. } \textbf{716}b.$$

For double chain-riveted lap joints:

$$V = \frac{4\, d + 1}{2}. \qquad \textbf{(132}h.\textbf{)} \quad \text{Art. } \textbf{716}b.$$

For double zigzag-riveted lap joints:

$$V = \frac{\sqrt{(11 p + 4 d)\,(p + 4 d)}}{10}. \qquad \textbf{(132}i.\textbf{)} \quad \text{Art. } \textbf{716}b.$$

$$p_a = \frac{6\,p + 4\,d}{10}. \qquad \textbf{(132}j.\textbf{)} \quad \text{Art. } \textbf{716}c.$$

For a single-riveted lap joint:

$$p_m = 1.31\,T + 1\tfrac{5}{8}''. \qquad \textbf{(132}k.\textbf{)} \quad \text{Art. } \textbf{716}c.$$

For a double-riveted lap joint:

$$p_m = 2.62\,T + 1\tfrac{5}{8}''. \qquad \textbf{(132}l.\textbf{)} \quad \text{Art. } \textbf{716}c.$$

STRESS IN STAYS.

A = area in square inches supported by a stay (whether screw stay, staybolt, or stayrod);

B = the cross-sectional area of the stay in square inches (corresponding to diameter at bottom of the thread, if the stay is screwed);

P = steam pressure in pounds per square inch;

L = load on the stay in pounds;

S = stress per square inch of cross-section of the stay;

S_t = total allowable stress on a stay;

M = legal stress per square inch of cross-section of the stay;

A_t = total area to be supported in square inches;

N = number of stays.

$$L = A\,P. \qquad \textbf{(133.)} \quad \text{Art. } \textbf{728.}$$

$$S = \frac{A\,P}{B}. \qquad \textbf{(134.)} \quad \text{Art. } \textbf{728.}$$

$$S_t = B\,M. \qquad \textbf{(134}a.\textbf{)} \quad \text{Art. } \textbf{728.}$$

$$P = \frac{B\,M}{A}. \qquad \textbf{(135.)} \quad \text{Art. } \textbf{728.}$$

$$N = \frac{A_t\,P}{S_t}. \qquad \textbf{(135}a.\textbf{)} \quad \text{Art. } \textbf{728.}$$

PALM STAYS.

b = distance in inches from boiler head to intersection of the center line of the palm stay with the shell;

l = length of the palm stay in inches, measured between head and shell along the center line of the stay;

A = area supported by the stay in square inches;
P = steam pressure in pounds;
M = legal stress per square inch of cross-section of the stay.

$$L = \frac{l}{b} A P. \qquad \textbf{(135}b.\textbf{)} \quad \text{Art. } \mathbf{729}a.$$

$$P = \frac{b}{l} \times \frac{B M}{A}. \qquad \textbf{(135}c.\textbf{)} \quad \text{Art. } \mathbf{729}c.$$

STRENGTH OF STAYED SURFACES.

P = working pressure in pounds per square inch;
t = thickness of plate in sixteenths of an inch;*
a = pitch of stays (arranged as in Fig. 186, Art. **727**).

When fitted with either screw stays, staybolts and nuts, or socket staybolts, and the surfaces are those of fire-boxes, furnaces, or back connections, we have:

When the plates do not exceed $\frac{7}{16}''$ in thickness:

$$P = \frac{112\, t^2}{a^2}. \qquad \textbf{(136.)} \quad \text{Art. } \mathbf{730.}$$

$$a = \sqrt{\frac{112\, t^2}{P}}. \qquad \textbf{(138.)} \quad \text{Art. } \mathbf{731.}$$

And when the plates exceed $\frac{7}{16}''$ in thickness:

$$P = \frac{120\, t^2}{a^2}. \qquad \textbf{(137.)} \quad \text{Art. } \mathbf{730.}$$

$$a = \sqrt{\frac{120\, t^2}{P}}. \qquad \textbf{(138.)} \quad \text{Art. } \mathbf{731.}$$

When the surfaces are other than those mentioned above, and stayrods with screwed ends are used, having nuts inside and out, as in Fig. 180, Art. **722,** we have

$$P = \frac{140\, t^2}{a^2}. \qquad \textbf{(139.)} \quad \text{Art. } \mathbf{732.}$$

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* NOTE.—In the following formulas—**136** to **140**—the symbol t^2 means "the square of the number of sixteenths contained in the thickness of the plate." Thus, if the plate is $\frac{3}{8}''$ thick, there are 6 sixteenths in its thickness, and, therefore, $t^2 = 6^2 = 36$.

When the conditions are the same as for formula **139**, except that the stayrods are provided with a square washer riveted to the head and having a thickness not less than half that of the plate, and the length of the side not less than seven-eighths of the pitch of the stayrod, formula **140** may be used, taking t at 80% of the combined thickness of plate and washer. Also, when a stiffening plate equal in thickness to at least half that of the head is used and securely riveted to the head, and when double angle irons riveted to the plate with stayrods between them and legs having a thickness not less than two-thirds that of the plate, and a depth of not less than one-quarter of the pitch of the stayrods, are used, 80% of the combined thickness is to be taken as the value of t; the working pressure allowed is then given by

$$P = \frac{200\,t^2}{a^2}. \qquad \textbf{(140.)} \quad \text{Art. } \textbf{733.}$$

BOILER FLUES.

Smoke Flues.

P = working pressure in pounds per square inch, given in Table 27, corresponding to diameter and thickness of flue;

L = corresponding length of sections of flue in above table;

P_1 = the required working pressure in pounds per square inch;

L_1 = actual length of sections of flue.

NOTE.—L and L_1 are to be measured between centers of circular seams.

Then, $$P_1 = \frac{PL}{L_1}. \qquad \textbf{(141.)} \quad \text{Art. } \textbf{736.}$$

Furnace Flues.

D = diameter of flue in inches;

T = thickness of flue in decimals of an inch;

L = length of flue in feet (not to exceed 8 feet);

P = working pressure in pounds per square inch.

$$P = \frac{89{,}600\,T^2}{L\,D}. \qquad \textbf{(142.)} \quad \text{Art. } \textbf{743.}$$

In furnaces made up in sections with flanged ends [see Fig. 190 (*A*), Art. **740**], L is to be taken as the length of each section, if not more than 8 feet; where each section is strengthened at equal intervals by angle-iron rings [Fig. 190 (*B*)], L is to be taken as the length of one of the portions into which the section is thus divided. Thus, if each section were $6\frac{1}{2}$ feet long, and a strengthening ring were fixed midway between the ends, the value of L would be taken as $3\frac{1}{4}$ feet. If the section were 10 feet long and two rings were used (equally spaced), L would be $\frac{10}{3} = 3\frac{1}{3}$ feet.

When the flues are strengthened with half-round rings [Fig. 190 (*C*)], we have

$$P = \frac{67{,}200\, T^2}{L\, D}. \qquad \textbf{(143.)} \quad \text{Art. } \textbf{743.}$$

L is to be taken in the same way as in previous rule.

Corrugated and Ribbed Furnace Flues.

T = thickness of flue in decimals of an inch;
D = mean diameter of flue in inches;
P = working pressure in pounds per square inch.

$$P = \frac{14{,}000\, T}{D}. \qquad \textbf{(144.)} \quad \text{Art. } \textbf{746.}$$

NOTE.—For corrugated flues D is to be taken as the outside diameter measured over bottom of corrugations, and in the case of ribbed flues, D is to be measured (outside) over the flat part of flue.

MORISON SUSPENSION FLUE.

The symbols having the same meaning as in the previous rule, and taking for D the outside diameter over the bottom of the corrugations, we have

$$P = \frac{15{,}000\, T}{D}. \qquad \textbf{(144}a.\textbf{)} \quad \text{Art. } \textbf{746}a.$$

HEADS OF BOILER OR STEAM DRUMS (UNSTAYED).

Bumped Heads.

P = working pressure in pounds per square inch;
T = thickness of head in inches;
R = radius in inches to which the head is bumped or dished;
A = area of flat head in square inches;
S = tensile strength of material in pounds per square inch.

When the concave or hollow side is subject to the steam pressure (Fig. 193 (*a*), Art. **747**), and the head is single riveted to the shell:

$$P = \frac{T\,S}{3\,R}. \qquad \textbf{(145.)} \quad \text{Art. } \textbf{747.}$$

When the head is double riveted to the shell:

$$P = \frac{T\,S}{2.5\,R}. \qquad \textbf{(145.)} \quad \text{Art. } \textbf{747.}$$

When the head is reversed, the hollow side being set outwards, away from the steam [Fig. 193 (*b*)], and the head is single riveted to the shell:

$$P = \frac{T\,S}{5\,R}. \qquad \textbf{(146.)} \quad \text{Art. } \textbf{748.}$$

When the head is double riveted to the shell:

$$P = \frac{T\,S}{4\tfrac{1}{6}R}. \qquad \textbf{(146.)} \quad \text{Art. } \textbf{748.}$$

For flat unstayed heads:

$$P = \frac{T\,S}{.54\,A}. \qquad \textbf{(147.)} \quad \text{Art. } \textbf{749.}$$

When these heads are stayed, the working pressure may be found by means of rules **135***c* and **139.**

BOILER SHELLS.

T = thickness of plate of cylinder or boiler in inches;
R = internal radius in inches;
S = ultimate tensile strength of the material;

P_b = bursting pressure in pounds per square inch;
P = safe working pressure in pounds per square inch.

$$P_b = \frac{T\,S}{R}. \qquad \textbf{(148.)} \quad \text{Art. } \textbf{752.}$$

For boilers with single-riveted longitudinal seams, the value of P is fixed by law, thus:

$$P = \frac{T\,S}{6\,R}. \qquad \textbf{(149.)} \quad \text{Art. } \textbf{753.}$$

For boilers with double-riveted longitudinal seams, the value of P by law is:

$$P = \frac{T\,S}{5\,R}. \qquad \textbf{(150.)} \quad \text{Art. } \textbf{754.}$$

The above rules assume that none of the rivet holes are punched, and also that corresponding holes match fairly without any drifting.

SAFETY VALVES.

A = area of the valve in square inches;
D = distance in inches from center line of valve to fulcrum;
L = distance in inches of weight from fulcrum;
P = steam pressure in pounds per square inch;
W = weight on the lever in pounds;
w = weight of valve and stem in pounds added to the downward pressure due to weight of lever.

NOTE.—By "the area of a safety valve" is meant the area of that part which is exposed to the steam pressure when the valve is seated.

$$P = \frac{\frac{W\,L}{D} + w}{A}. \qquad \textbf{(151.)} \quad \text{Art. } \textbf{767.}$$

$$L = \frac{(A\,P - w)\,D}{W}. \qquad \textbf{(152.)} \quad \text{Art. } \textbf{767.}$$

$$W = \frac{(A\,P - w)\,D}{L}. \qquad \textbf{(153.)} \quad \text{Art. } \textbf{768.}$$

SATURATION AND THE SALINOMETER.

Testing the Water in Boiler.

A = boiling point of water tested;
B = product of the number of tenths of an inch variation in the height of barometer and .16; this product to be subtracted when the barometer is above 30 in., and added when below 30 in.;
S = the degree of saturation of the water. (S will be the numerator of the fraction expressing the saturation.)

$$S = \frac{(A \pm B) - 212}{1.2}. \qquad \textbf{(154.)} \quad \text{Art. } \textbf{817.}$$

Amount of Water To Be Blown Off.

A = weight of water to be blown off in pounds;
B = numerator of fraction expressing the saturation of A;
C = weight of feed-water in pounds;
D = numerator of fraction expressing the saturation of C;
E = weight of water evaporated, corresponding to C.

$$A = \frac{CD}{B}. \qquad \textbf{(155.)} \quad \text{Art. } \textbf{820.}$$

$$E = A\left(\frac{B}{D} - 1\right). \qquad \textbf{(156.)} \quad \text{Art. } \textbf{820.}$$

Loss of Heat Due to Blowing Off.

A = total heat (reckoned above the temperature of the feed) imparted to the amount of water converted into steam for 1 pound of water blown off;
B = number of B. T. U. lost in blowing off 1 pound of water;
L = percentage of heat lost.

$$L = \frac{100\,B}{A + B}. \qquad \textbf{(157.)} \quad \text{Art. } \textbf{822.}$$

COMBUSTION.

Particulars of Combustion.—Evaporation.

C = the number of parts of carbon contained in 100 parts of a given fuel;

H = the number of parts of hydrogen contained in 100 parts of the same fuel;

A = the number of cubic feet of air required for the combustion of a pound of the above fuel;

B = heat of combustion of a pound of the fuel in B. T. U.;

W = number of pounds of water at 212° evaporated by a pound of the above fuel.

$A = 1.52\,(C + 3\,H)$. **(158.)** Art. **838.**

$B = 145\,C + 620\,H$. **(159.)** Art. **839.**

$W = \frac{B}{966}$. **(160.)** Art. **839.**

Rate of Combustion Under Natural Draft.

W = maximum weight (in pounds) of coal burned per square foot of grate area per hour;

H = height of smokestack in feet.

NOTE.—The height of smokestack is the perpendicular distance between the top of the stack and the top of the grate.

Anthracite coal burning under the most favorable conditions:

$W = 2\sqrt{H} - 1$. **(161.)** Art. **853.**

Anthracite coal burning under ordinary conditions:

$W = 1.5\sqrt{H} - 1$. **(162.)** Art. **853.**

The best semi-anthracite and bituminous coals:

$W = 2.25\sqrt{H}$. **(163.)** Art. **853.**

Ordinary soft coals:

$W = 3\sqrt{H}$. **(164.)** Art. **853.**

GRATE AREA AND HEATING SURFACE.

G = area of grate in square feet;
H = area of heating surface in square feet;
F = rate of combustion in pounds per square foot of grate area per hour;
W = weight of steam generated by boiler per hour;
E = pounds of water evaporated per pound of coal per hour;
R = ratio of heating surface to grate area; it is from 30 to 35 for Scotch or fire-box boilers, and from 35 to 40 for water-tube boilers.

$$G = \frac{W}{F E}. \qquad \textbf{(165.)} \quad \text{Art. } \textbf{900.}$$

$$H = R G. \qquad \textbf{(166.)} \quad \text{Art. } \textbf{901.}$$

EVAPORATIVE POWER OF BOILERS.

W = the actual evaporation;
W_1 = equivalent evaporation from and at 212° F.;
H = total heat of steam above 32° F. at pressure of actual evaporation;
t = observed temperature of feed-water.

$$W_1 = \frac{W(H - t + 32)}{966.1}. \qquad \textbf{(167.)} \quad \text{Art. } \textbf{927.}$$

QUALITY OF STEAM.

W = weight in pounds of cold water, into which the steam to be tested is run;
w = weight of steam (including any water carried over by it) that is run in;
t = temperature of steam corresponding to the observed pressure;
t_1 = original temperature of the water W;
t_2 = temperature of the mixture after the steam is condensed;

l = latent heat of a pound of steam at the observed pressure;
x = the portion of the weight w that is dry steam;
Q = the quality of the steam $= \frac{x}{w}$.

Then,

$$Q = \frac{x}{w} = \frac{1}{l}\left[\frac{W}{w}(t_2 - t_1) - (t - t_2)\right]. \qquad \textbf{(168.)} \quad \text{Art. } \textbf{929.}$$

FORMULAS USED IN STEAM ENGINES.

WORK DONE BY PISTON.

p = net pressure on piston in pounds per square inch;
V = volume in cubic feet displaced by piston (= area of piston × length of stroke);
W = work done during one stroke.

$$W = 144 p V. \qquad \textbf{(169.)} \quad \text{Art. } \textbf{937.} \quad \S\ 9.$$

REAL AND APPARENT CUT-OFFS.

s = apparent cut-off;
k = real cut-off;
i = the clearance, expressed as a per cent. of stroke.

$$k = \frac{s + i}{1 + i}. \qquad \textbf{(170.)} \quad \text{Art. } \textbf{994.} \quad \S\ 9.$$

SLIP.

P = percentage of slip;
V = velocity of issuing stream in regard to the vessel;
V_1 = velocity of vessel.

$$P = 100 \times \frac{V - V_1}{V}. \qquad \textbf{(171.)} \quad \text{Art. } \textbf{1001.} \quad \S\ 9.$$

CENTER OF PRESSURE IN A PADDLE WHEEL.

P = distance of center of pressure from outer edge of buckets in inches;
a = mean depth in inches of buckets wholly immersed;
b = number of buckets so immersed;
c = mean depth in inches of buckets partially immersed;
d = number of buckets so immersed;
D = diameter of wheel, measured over outer edge of buckets;
D_e = effective diameter.

$$\left.\begin{array}{ll} P = \dfrac{ab + cd}{3(b + d)}. & (a) \\ D_e = D - 2P. & (b) \end{array}\right\} \quad \textbf{(172.)} \quad \text{Art. } \textbf{1003.} \quad \S\, 9.$$

ROLLING CIRCLE OF PADDLE WHEEL.

S = distance moved by the vessel in feet;
R = number of revolutions of the wheel made while vessel moves through above distance;
D = diameter of rolling circle.

$$D = \frac{S}{3.1416\,R}. \qquad \textbf{(173.)} \quad \text{Art. } \textbf{1008.} \quad \S\, 9.$$

THRUST.

Theoretical Thrust.

W = weight of stream projected from the vessel (whether by paddle, screw, or jet);
V = its velocity, in regard to the surrounding water, in feet per second;
g = 32.16, a constant;
T = the theoretical thrust.

$$T = \frac{WV}{g}. \qquad \textbf{(174.)} \quad \text{Art. } \textbf{1018.} \quad \S\, 9.$$

Indicated Thrust.

H = indicated horsepower of the engines;
P = pitch of screw propeller in feet;
D_e = effective diameter of paddle wheel in feet;
R = revolutions per minute;
T_i = indicated thrust.

For screw steamer:

$$T_i = \frac{33{,}000\,H}{PR}. \qquad \textbf{(175.)}\ \text{Art. } \textbf{1022.}\ \S\,9.$$

For paddle steamer:

$$T_i = \frac{33{,}000\,H}{3.1416\,D_e R}. \qquad \textbf{(176.)}\ \text{Art. } \textbf{1023.}\ \S\,9.$$

SPEED OF VESSELS.

Indicated Horsepower and Speed of Vessel.

H = indicated horsepower;
W = displacement of vessel in tons;
k = a constant (see table of Constants for Speed Formulas);
S = speed in knots.

$$H = \frac{S^3 \sqrt[3]{W^2}}{k}. \qquad \textbf{(177.)}\ \text{Art. } \textbf{1028.}\ \S\,9.$$

Revolutions of Engine and Speed of Vessel.

R = revolutions per minute for a given speed;
S = given speed;
R_1 = required revolutions per minute;
S_1 = required speed.

$$R_1 = \frac{R\,S_1}{S}. \qquad \textbf{(178.)}\ \text{Art. } \textbf{1030.}\ \S\,9.$$

HORSEPOWER OF ENGINES.

H_1 = required indicated horsepower;
R_1 = revolutions per minute at the required horsepower;
H = given indicated horsepower;
R = revolutions per minute corresponding to it.

$$H_1 = \frac{R_1^3 H}{R^3}.$$ **(179.)** Art. **1032.** § 9.

INDICATED HORSEPOWER.

I. H. P. = indicated horsepower of engine;
P = mean effective pressure (M. E. P.) in pounds per square inch;
A = area of piston in square inches;
L = length of stroke in feet;
N = number of strokes per minute.

$$\text{I. H. P.} = \frac{PLAN}{33{,}000}.$$ **(180.)** Art. **1067.** § 10.

MEAN EFFECTIVE PRESSURE.

p = gauge pressure;
k = a constant corresponding to the apparent cut-off (see table of Constants for Apparent Cut-Offs);
M. E. P. = mean effective pressure.

$$\text{M. E. P.} = .9\,[k\,(p + 14.7) - 17].$$ **(181.)** Art. **1068.** § 10.

PISTON SPEED.

l = length of stroke in inches;
R = number of revolutions per minute;
S = piston speed in feet per minute.

$$S = \frac{lR}{6}.$$ **(182.)** Art. **1069.** § 10.

MECHANICAL EFFICIENCY OF ENGINE.

I. H. P. = indicated horsepower, or total horsepower developed;

Friction H. P. = horsepower absorbed in overcoming the frictional resistance of engine itself;

Net H. P. = the net horsepower; that is, the horsepower remaining for the performance of useful work = I. H. P. − Friction H. P.;

E_m = mechanical efficiency of engine.

$$E_m = \frac{\text{Net H. P.}}{\text{I. H. P.}}.\qquad \textbf{(183.)}\ \text{Art. } \textbf{1073.}\ \ \S\,10.$$

STEAM CONSUMPTION.

l = distance in inches between two points on the diagram, one on the expansion line and the other on the compression line, both equally distant from the vacuum line;

a = pressure of steam at the above points;

W = weight of a cubic foot of steam at the above pressure;

L = length of diagram in inches (as *e h*, Fig. 320, Art. **1074**);

Q = steam consumption in pounds per I. H. P. per hour.

$$Q = \frac{13,750\, l\, W}{PL}.\qquad \textbf{(184.)}\ \text{Art. } \textbf{1078.}\ \ \S\,10.$$

THERMAL EFFICIENCY OF ENGINE.

T_1 = absolute temperature of steam on entering the cylinder;

T_2 = absolute temperature of steam on leaving the cylinder;

E_T = thermal efficiency.

$$E_T = \frac{T_1 - T_2}{T_1}.\qquad \text{Art. } \textbf{1081.}\ \ \S\,10.$$

WATER REQUIRED FOR CONDENSATION.

t_1 = temperature of departing condensing water;
t_2 = temperature of entering condensing water;
t_3 = temperature of condensed steam upon leaving condenser;
H = total heat of vaporization of one pound of steam at the pressure of the exhaust. (This may be obtained from column 5 of the table of Properties of Saturated Steam.)
W = number of pounds of water required to condense a pound of steam.

$$W = \frac{H - t_3 + 32}{t_1 - t_2}. \qquad \textbf{(185.)} \quad \text{Art. } \mathbf{1096.} \quad \S\, 10.$$

RATIO OF EXPANSION.

e = ratio of expansion in high-pressure cylinder;
E = total ratio of expansion;
v = volume of cylinder receiving steam from boiler;
V = volume of cylinder exhausting into atmosphere or condenser.

$$E = \frac{e\,V}{v}. \qquad \textbf{(186.)} \quad \text{Art. } \mathbf{1103.} \quad \S\, 10.$$

FEED-WATER.

a = numerator of the fraction expressing the saturation at which the boiler is to be worked;
b = net feed-water per stroke in cubic inches;
c = gross feed-water (i. e., the quantity of water per stroke of the feed-pump).

$$c = \frac{a\,b}{a - 1}. \qquad \textbf{(187.)} \quad \text{Art. } \mathbf{1155.} \quad \S\, 10.$$

FORMULAS USED IN RECENT DEVELOPMENTS IN MARINE ENGINEERING.

REFRIGERATING CAPACITY.

F = refrigerating capacity;
H = B. T. U. abstracted in 24 hours.

$$F = \frac{H}{288{,}000}. \qquad \text{Art. } \mathbf{9.} \quad \S\, 12.$$

RULES AND FORMULAS USED IN DYNAMOS AND MOTORS.

DIRECTION OF LINES OF FORCE AROUND A CONDUCTOR.

Rule.—*If the current is flowing in the conductor away from the observer, then the direction of the lines of force will be around the conductor in the direction of the hands of a watch.* Art. **26.** § 28.

TO DETERMINE THE POLARITY OF A SOLENOID.

Rule.—*In looking at the end of the helix, if it is so wound that the current circulates around the helix in the direction of the hands of a watch, that end will be a south pole; if in the other direction, it will be a north pole.* Art. **29.** § 28.

RESISTANCE OF CONDUCTORS.

Let r_1 = the original resistance of a conductor;
r_2 = the changed resistance;
l_1 = the original length;
l_2 = the changed length;
a_1 = the original sectional area;
a_2 = the changed sectional area;
D = the original diameter;
d = the changed diameter;
k = temperature coefficient;
t = rise or fall in temperature, degrees Fahrenheit.

For a change in the length of a conductor:

$$r_2 = \frac{r_1 l_2}{l_1}. \qquad (1.) \quad \text{Art. } \mathbf{40.} \quad \S\ 28.$$

For a change in the sectional area of a conductor:

$$r_2 = \frac{r_1 a_1}{a_2}. \qquad (2.) \quad \text{Art. } \mathbf{41.} \quad \S\ 28.$$

For a change in the diameter of a conductor:

$$r_2 = \frac{r_1 D^2}{d^2}.$$ **(3.)** Art. **42.** § 28.

For a rise in the temperature of a conductor:

$$r_2 = r_1 (1 + t k).$$ **(4.)** Art. **46.** § 28.

For a fall in the temperature of a conductor:

$$r_2 = \frac{r_1}{1 + t k}.$$ **(5.)** Art. **47.** § 28.

RESISTANCES AND TEMPERATURE COEFFICIENTS OF DIFFERENT METALS.

Name of Metal.	Resistance, Microhms per Cu. In.	Relative Resistance.	Temperature Coefficient.
Silver, annealed.......	.5921	1.000	.002094
Copper, annealed......	.6292	1.063	.002155
Silver, hard-drawn....	.6433	1.086	.002094
Copper, hard-drawn...	.6433	1.086	.002155
Gold, annealed........	.8102	1.369	.002028
Gold, hard-drawn.....	.8247	1.393	.002028
Aluminum, annealed..	1.1470	1.935	....
Zinc, pressed.........	2.2150	3.741	.002028
Platinum, annealed....	3.5650	6.022	....
Iron, annealed........	3.8250	6.460	....
Nickel, annealed......	4.9070	8.285	....
Tin, pressed..........	5.2020	8.784	.002028
Lead, pressed.........	7.7280	13.050	.002150
German Silver........	8.2400	13.920	.000244
Antimony, pressed....	13.9800	23.600	.002161
Mercury..............	37.1500	62.730	.000400
Bismuth, pressed......	51.6500	87.230	.001967

CURRENT STRENGTH, ELECTROMOTIVE FORCE, AND RESISTANCE.

Let C = strength of current flowing in a closed circuit;
E = electromotive force;
R = resistance.

$$C = \frac{E}{R}. \qquad \textbf{(6.)} \quad \text{Art. } \textbf{61.} \quad \S\, 28.$$

$$R = \frac{E}{C}. \qquad \textbf{(7.)} \quad \text{Art. } \textbf{62.} \quad \S\, 28.$$

$$E = C R. \qquad \textbf{(8.)} \quad \text{Art. } \textbf{63.} \quad \S\, 28.$$

TO FIND THE AVAILABLE ELECTROMOTIVE FORCE IN A CELL.

Let E = the total generated E. M. F.;
E' = *available* E. M. F. when the circuit is closed;
C = the current flowing when the circuit is closed;
r_i = the internal resistance of the cell.

$$E' = E - C r_i. \qquad \textbf{(9.)} \quad \text{Art. } \textbf{67.} \quad \S\, 28.$$

THE CURRENT AND RESISTANCE IN BRANCHES OF DIVIDED CONDUCTORS.

Let r_1 = resistance of first branch;
r_2 = resistance of second branch;
r_3 = resistance of third branch;
c_1 = current in first branch;
c_2 = current in second branch;
C = sum of the currents in the two branches;
R'' = joint resistance of two branches in parallel;
R''' = joint resistance of three branches in parallel.

$$c_1 = \frac{C r_2}{r_1 + r_2}. \qquad \textbf{(10.)} \quad \text{Art. } \textbf{69.} \quad \S\, 28.$$

$$c_2 = \frac{C r_1}{r_1 + r_2}. \qquad \textbf{(11.)} \quad \text{Art. } \textbf{69.} \quad \S\, 28.$$

$$R'' = \frac{r_1 r_2}{r_1 + r_2}. \qquad \textbf{(12.)} \quad \text{Art. } \textbf{71.} \quad \S\, 28.$$

$$R''' = \frac{r_1 r_2 r_3}{r_2 r_3 + r_1 r_3 + r_1 r_2}. \qquad \textbf{(13.)} \quad \text{Art. } \textbf{72.} \quad \S\, 28.$$

ELECTRICAL QUANTITY.

Let Q = quantity of electricity in coulombs;
C = current strength in amperes;
t = time in seconds.

$Q = Ct.$ **(14.)** Art. **76.** § 28.

ELECTRICAL WORK AND POWER.

J = electrical work in joules;
F. P. = work in foot-pounds;
Q = quantity of electricity in coulombs;
C = current in amperes;
t = time in seconds during which the current flows;
E = potential, or E. M. F., of circuit;
R = resistance of circuit;
W = power in watts;
H. P. = horsepower.

$J = CEt.$ **(15.)** Art. **78.** § 28.

$J = C^2 Rt.$ **(16.)** Art. **78.** § 28.

$J = \frac{E^2 t}{R}.$ **(17.)** Art. **78.** § 28.

F. P. = $.7373 J.$ **(18.)** Art. **79.** § 28.

$W = CE.$ **(19.)** Art. **80.** § 28.

$W = C^2 R.$ **(20.)** Art. **80.** § 28.

$W = \frac{E^2}{R}.$ **(21.)** Art. **80.** § 28.

H. P. = $\frac{W}{746}.$ **(22.)** Art. **81.** § 28.

W = H. P. × 746. **(23.)** Art. **82.** § 28.

TO DETERMINE THE DIRECTION OF THE CURRENT GENERATED IN A CONDUCTOR.

Rule.—*Place thumb, forefinger, and middle finger of the right hand so that each will be perpendicular to the other two; if the forefinger points in the direction of the lines of force and the thumb points in the direction towards which the conductor is moving, then the middle finger will point in the direction towards which the current generated in the conductor tends to flow.* Art. **8.** § 29.

DETERMINATION OF ELECTROMOTIVE FORCE.

Let E = maximum electromotive force obtained at the brushes;

N = total number of lines of force passing from north pole through the core to the south pole;

S = number of outside wires on the periphery through which the current flows *in series;*

n = number of complete revolutions per second of core.

$$E = \frac{2NSn}{10^8}. \qquad \textbf{(1.)} \quad \text{Art. } \mathbf{23.} \quad \S\ 29.$$

TO DETERMINE THE DIRECTION OF MOTION IMPARTED TO A CONDUCTOR.

Rule.—*Place thumb, forefinger, and middle finger of the left hand each at right angles to the other two; if the forefinger points in the direction of the lines of force and the middle finger points in the direction towards which the current flows, then the thumb will point in the direction of movement imparted to the conductor.* Art. **26.** § 29.

EFFICIENCY OF A DYNAMO.

Let I = input of a dynamo;

O = output;

E = efficiency, per cent.

$$\mathsf{E} = \frac{100 \times O}{I}. \qquad \textbf{(2.)} \quad \text{Art. } \mathbf{60.} \quad \S\ 29.$$

PER CENT. LOSS IN A DYNAMO.

Let L = per cent. loss;
I = input;
O = output.

$$L = \frac{100(I - O)}{I}. \qquad \textbf{(3.)} \quad \text{Art. } \textbf{61.} \quad \S\ 29.$$

When the output and efficiency are given:

$$I = \frac{100 \times O}{\mathsf{E}}. \qquad \textbf{(4.)} \quad \text{Art. } \textbf{62.} \quad \S\ 29.$$

When the input and efficiency are given:

$$O = \frac{I\mathsf{E}}{100}. \qquad \textbf{(5.)} \quad \text{Art. } \textbf{63.} \quad \S\ 29.$$

HORSEPOWER, TORQUE, AND NUMBER OF REVOLUTIONS OF MOTORS.

Let H. P. = horsepower;
T = torque;
S = number of revolutions per minute.

$$\text{H. P.} = .0001904\ TS. \qquad \textbf{(3.)} \quad \text{Art. } \textbf{62.} \quad \S\ 30.$$

$$S = \frac{\text{H. P.}}{.0001904\ T}. \qquad \textbf{(4.)} \quad \text{Art. } \textbf{62.} \quad \S\ 30.$$

$$T = \frac{\text{H. P.}}{.0001904\ S}. \qquad \textbf{(5.)} \quad \text{Art. } \textbf{62.} \quad \S\ 30.$$

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